PARAMETER IDENTIFICATION OF SERVO-PNEUMATIC POSITION CONTROL SYSTEM UTILIZING LEAST SQUARE ESTIMATE (LSE) APPROACH

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical Engineering (Hons.) (Electronics)

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23 NOVEMBER 2009

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Date : 23 NOVEMBER 2009

ACKNOWLEDGEMENTS

In the name of Allah S.W.T, the Most Gracious, the Ever Merciful. Praise is to Allah, Lord of the Universe and Peace and Prayers be upon His final Prophet and Messenger Muhammad s.a.w.

This thesis has only been made possible with the help of many parties. Above all, I would like to express my appreciation to my supervisor, Mr. Mohd. Syakirin bin Ramli for his guidance, ideas, advice and patience in supervising this project.

My sincere gratitude also goes to my colleagues for their aid, ideas and advice, and my lecturers and my friends who had helped me directly or indirectly especially to Nur Azmina Othman.

I would like also to express my appreciation to all lab technicians for their help and permission to use lab and equipment needed in this project.

Finally, special thanks extended to my beloved family especially my mother, Mrs Ros Lindawati binti Md Nadzir and my father, Mr. Mohamed Azmi bin Ramli who had given me the moral support and prayed for my success.

ABSTRACT

This project focused on the parameter identification of Servo-Pneumatic Position Control System (SPPCS) utilizing Least Square Estimate (LSE) approach. The obtained mathematical is analyzed in terms of transient and steady-state response. Presented method is based on the transfer function estimation, these were identified in calculation of the collection of the input and output data by using the LSE method approach. The mathematical model's parameter is estimated from the calculation. The mathematical model estimation is implemented using the MATLAB's simulation. The output performance from both MATLAB and Visual Basic (VB) will be compared and if the result is similar and the average error, e is smaller, then the results are accepted. The result obtained is a mathematical model that will be used as parameter identification for SPPCS. In the future, this parameter identification can be used to represent the whole of SPPCS in the MATLAB's simulation to replace the actual hardware.

ABSTRAK

Kertas kerja ini bertujuan untuk mengenalpasti satu model matematik (persamaan matematik) untuk *Servo-Pneumatic Position Control System* (SPPCS) melalui kaedah *Least Square Estimate (LSE)* dan juga menganalisis bentuk graf bagi aktiviti system ini dalam bentuk *transient* and *steady-state response*. Kaedah yang digunakan adalah berasaskan pengiraan *transfer function.* Bagi melaksanakan kaedah ini matlumat daripada *input dan output* sistem ini perlu direkodkan. Persamaan matematik untuk sistem ini dapat dikenalpasti daripada kaedah LSE. Dalam mengenalpasti persamaan matematik ini, perisian MATLAB dan perisian Visual Basic digunakan. Keluaran output bagi sistem ini dibandingkan dengan menggunakan MATLAB's simulation. Berdasarkan model simulasi dan model sebenar SPPCS, persamaan matematik dapat dibuktikan dan dapat diaplikasikan dalam kehidupan sebenar. Diakhir projek ini, sistem ini berupaya menunjukkan model matematik (persamaan) untuk SPPCS dengan kaedah LSE dan keluaran output bagi system dapat ditunjukkan dalam bentuk *transient* and *steady-state response*. Model metametik ini boleh digunakan bagi mewakili keseluruhan SPPCS dalam bentuk simulasi MATLAB untuk masa hadapan.

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LIST OF SYMBOL

$u(k)$	-	Input Data Sequences
$y(k)$	-	Output Data Sequences
p	-	Parameter Vector
M	-	Vector of Regression Variables
mv	-	Manipulated Variables
cv	-	Controlled Variable

LIST OF ABBREVIATION

I/P	-	Input
O/P	-	Output
PLC	-	Programmable Logic Controller
SPPCP	-	Servo-Pneumatic Position Control System
LSE	-	Least Square Estimate

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CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 Parameter Identification

There is a mathematical model for just about everything. Computer programs have been written to describe the flow of water in channels, the flow of electricity in conductors of strange shape, the growth of plants, the population dynamics of ants, the distribution of stress in the hulls of ships and on and on. Modeling programs generally require data of four main types.

These are:

- Fixed data
- Parameters
- Excitations
- Control data

The purpose of a mathematical model is to produce numbers. These numbers are the model's predictions of what a natural or man-made system will do under a certain excitation regime. It is for the sake of these numbers that the model was built, be it a ten line program involving a few additions and subtractions, or a complex numerical procedure for the solution of coupled sets of nonlinear partial differential equations.

Where a model simulates reality it often happens that the model-user does not know what reality is; in fact models are often used to obtain reality by comparing the numbers that they produce with numbers obtained from some kind of measurement. Thus if a model's parameter or excitation data are "tweaked", or adjusted, until the model produces numbers that compare well with those yielded by measurement, then perhaps it can be assumed that the excitations or parameters so obtained have actually told us something which we could not obtain by direct observation.

1.1.2 Least Square Estimate (LSE)

The least square method is widely used to find or estimate the numerical values of the parameters to fit a function to a set of data and to characterize the statistical properties of estimates. It exists with several variations: Its simpler version is called ordinary least squares (OLS), a more sophisticated version is called weighted least squares (WLS), which often performs better than OLS because it can modulate the importance of each observation in the final solution. Recent variations of the least square method are alternating least squares (ALS) and partial least squares (PLS).

The biggest advantage of nonlinear least squares regression over many other techniques is the broad range of functions that can be fit. Although many scientific and engineering processes can be described well using linear models, or other relatively simple types of models, there are many other processes that are inherently nonlinear. There are many types of nonlinear models, on the other hand, that describe the asymptotic behavior of a process well. Like the asymptotic behavior of some processes, other features of physical processes can often be expressed more easily using nonlinear models than with simpler model types.

Being a "least squares" procedure, nonlinear least squares has some of the same advantages (and disadvantages) that linear least squares regression has over other methods. One common advantage is efficient use of data. Nonlinear regression can produce good estimates of the unknown parameters in the model with relatively small data sets. Another advantage that nonlinear least squares shares with linear least squares is a fairly well-developed theory for computing confidence, prediction and calibration intervals to answer scientific and engineering questions. It is perhaps the most widely used technique in geophysical data analysis, which can be applied to any problem. In least squares the parameters to be estimated must arise in expressions for the means of the observations. When the parameters appear linearly in these expressions then the least squares estimation problem can be solved in closed form, and it is relatively straightforward to derive the statistical properties for the resulting parameter estimates.

1.1.3 Servo -Pneumatic Position Control System

Modern servo-pneumatic positioning technology has made significant inroads in the automated manufacturing environment. The advantages cited by end users include the speed of motion, low cost of installation and maintenance, cleanliness, and the simplicity of operation of these systems relative to other similar hydraulic and electro-mechanical technologies. The robustness of servo-pneumatic technology solutions is limited by the positioning accuracy of current system controllers. Servo-pneumatic controllers typically rely on sophisticated control algorithms that accommodate the highly non-linear nature of pneumatic actuator operation.

Advantages cited by end users of these systems include the speed of motion, low cost of installation and maintenance, cleanliness, and the simplicity of operation of these systems relative to other similar hydraulic and electro-mechanical technologies. These characteristics have a very positive impact on the use of these systems in the educational laboratory environment. The robustness of these servo-pneumatic actuator systems is typically limited only by the positioning accuracy of system controller.

The servo-pneumatic system consists of the following components:

- PLC (CJ1M-CPU 12)
    - A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or lighting fixtures.

- Cylinder Positioner
    - Cylinder positioner using pneumatic system is mechanical devices which produce force, often in combination with movement, and are powered by compressed gas.

- Electro-Pneumatic Regulator
    - An electro-pneumatic regulator system for controlling a pressure and a current that supplied from a source on the basis of a level of an input electric signal
- LVDT Transducer
    - The linear variable differential transformer (LVDT) is a type of electrical transformer used for measuring linear displacement.

1.2 Problem Statement

In this project, the major statement consists of Parameter Identification and Servo-Pneumatic Position Control System. Pneumatic actuators provide solutions through motion technology in many applications. A wide range of industries now rely on pneumatics since pneumatic actuators have distinct advantages: clean for environment, rapid point-to-point positioning, high load-carrying capacity-to-size ratio, mechanical simplicity, low cost, and ease in maintenance. For Parameter Identification, it is useful for computer simulation, mechatronic design and also for control algorithm design.

1.3 Objective

The main objectives of this project are:

- To identify and obtain the mathematical characteristic of the Servo-Pneumatic Position Control system using a suitable parameter identification and estimation techniques.
- To analyze the performance in terms transient and steady-state response

1.4 Scope of Project

This project is to identify a mathematical model for Servo-Pneumatic Position Control using Least Square Estimate that can be used by implement the parameter equation in MATLAB’s Simulation. As a machine’s performance is a vital factor for a big production line, this project will examine the efficiency and performance of a pneumatic cylinder by comparing the experimental model with real model . Then, the performance of the system will show in term of transient and steady state respond using GUI software. Thus, the focuses of this project are as stated below:

- To set up OMRON CJ1M-CPU 12 Programmable Logic Control and the PLC card.
- To develop the GUI that will analyze the experimental performance in terms of graph.
- To determine a mathematical characteristic that similar with model of the servo-pneumatic system by using parameter identification.
- To perform the simulation of this project by using MATLAB’s Simulink.
- To compare the simulation and experimental in term of the output response.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focused on the literature review for each component in this project. All the component is described in details based on the finding during the completion of this project. The device and method that will be discussed about application in this chapter are:

- Servo-Pneumatic Position Control System
- Parameter Identification
- Programmable Logic Controller
- Least Square Estimate
- MATLAB's Simulation
- Graphical User Interface (GUI)